BEYOND THE LEVELS OF DOMESTICATION IN FISH: MUST ALL FARMED SPECIES BE DOMESTICATED?

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DOMESTIFIKACIJA RIBA: MORAJU LI SVE GAJENE VRSTE BITI DOMESTIFIKOVANE?

UVOD

Danas u poljoprivredi dominira nekoliko vrsta sisara koje su domestifikovane pre više od 12 000 godina (Diamond, 2002). Pet najprisutnijih vrsta (goveda, svinje, ovce, koze i konji) danas predstavljaju skoro 94% stoke sisara. Kao posledica toga, danas postoji jasna razlika između brojnih divljih (iz lova) i nekoliko domestifikovanih vrsta (proizvedenih na farmama) kojima se čovek hrani. Slično poljoprivredi, na akvakulturu se često gleda kao na jedino rešenje koje može da obezbedi više hrane iz mora obzirom da je ulov marinskih vrsta ili stabilizovan ili u opadanju od kasnih osamdesetih godina prošlog veka (Watson and Pauly, 2001; FAO, 2012). I zaista, malo je verovatno da će ribarstvo biti u mogućnosti da proizvede vise morskih prehrambenih proizvoda nego danas, *ca.* 90 miliona tona godisnje, uključujući i mora i kopnene vode (FAO, 2012). Ipak, u poređenju sa poljoprivredom, akvakultura je značajno mlađi sektor koji se veoma oslanja na prirodne izvore u proizvodnji brojnih vrsta sa promenljivim nivoom proizvodnje (Bostock et al., 2010; Jobling, 2010). Od 313 vrsta ili grupa vrsta koje su zabeležene u bazi podataka Organizacije za hranu i poljoprivredu Ujedinjenih Nacija (FAO) iz 2009-te godine a koje su gajene od 1950te, 28.4% se više nije proizvodilo u 2009. godini a 17.9% imalo je proizvodnju nižu od 100 tona. Samo 12.1% vrsta ima proizvodnju višu od 100 000 tona (Teletchea and Fontaine, 2013). Staviše, trajanje konsekutivne proizvodnje zabeležene u FAO-voj bazi podataka bilo je veoma kratko za većinu vrsta ili grupa vrsta: samo jedna godina za 10.2% i od dve do pet godina za 15.3%. Samo je 18.8% bilo gajeno više od četrdeset godina (Teletchea and Fontaine, 2013).

Da bi se bolje opisale različite strategije proizvodnje ribe (Ottolenghi et al., 2004; Welcomme et al., 2010; Klinger et al., 2013), nedavno je predložena nova klasifikacija koja se sastoji od pet nivoa "domestifikacije", gde je 1 oznaka za najmanje a 5 oznaka za najviše domestifikovane vrste (Teletchea and Fontaine, 2013). Od 250 vrsta zabeleženih u FAO-voj bazi podataka iz 2009-te (osim isključenih vrsta), 39 pripada nivou 1 (prvi pokušaji privikavanja na uzgojnu sredinu, npr. *Anguilla rostrata*; *Scardinius erythrophthalmus)*, 75 pripada nivou 2 (ovaj nivo se takođe naziva 'akvakultura bazirana na ulovu', npr. *Thunnus thynnus, Aspius aspius*), 61 vrsta pripada nivou 3 (one vrste koje su ceo zivot zatočene, sa novim vrstama iz divljine, npr *Solea senegalensis, Rutilus rutilus*), 45 pripada nivou 4 (one vrste koje su ceo život zatočene, bez novih vrsta iz divljine, npr. *Pagrus pagrus, Sander lucioperca*), i 30 pripada nivou 5 (program selektivnog gajenja koji ima određen cilj, npr. *Salmo salar, Cyprinus carpio*). Od danas, 70% od 250 vrsta riba koje se nalaze na FAO-voj listi spadaju u prva tri nivoa domestifikacije koja zavise od dostupnosti divljih resursa (Ottolenghi et al., 2004). Nasuprot tome, samo nekoliko vrsta, ili tačnije populacija, se mogu smatrati potpuno domestifikovanim (Balon, 2004; Bilio, 2008), npr. životinja selektivno gajena u zatočeništvu i izmenjena u odnosu na svoje pretke je veoma značajna za ljude koji kontrolišu gajenje životinja i njihovu ishranu (Clutton-Brock, 1999), slično govedima i ovcama.

Zasnovano na ovoj novoj klasifikaciji, možemo se zapitati da li gajene vrste moraju biti domestifikovane da bi dostigle značajni nivo proizvodnje? Ili, drugim rečima, da li su nivoi proizvodnje i domestifikacija u pozitivnoj korelaciji?

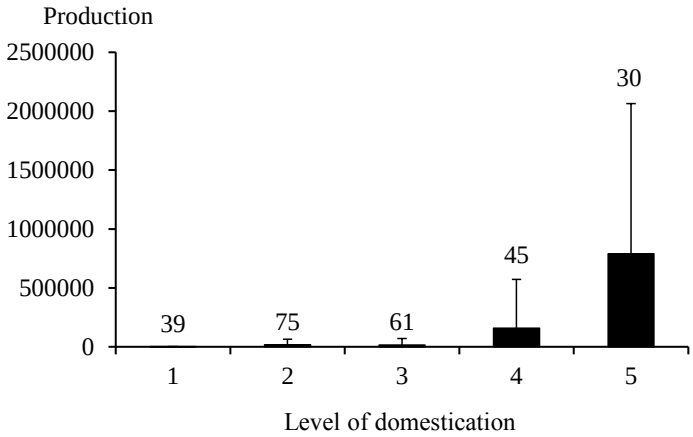
MATERIJALI I METODE

Ovakve analize zahtevaju postojanje preciznih podataka o: (i) nivou domestifikacije svake vrste, (ii) globalnoj proizvodnji po vrsti, i (iii) procentualnom iznosu proizvodnje po nivou domestifikacije za svaku vrstu. Iz 2 baze podataka: 'Teletchea and Fontaine' iz 2013-te i FAO (http://www.fao.org/fishery/en), mogu se dobiti prve dve vrste podataka. Ipak, s obzirom na prirodu podataka koje su FAO-vi članovi i pridružene nacije dale FAO-u (Klinger et al., 2013), trenutno je nemoguće znati koliko jedna vrsta proizvodi u vezi sa njenim nivoom domestifikacije. I zaista, kao što je ranije primećeno, dostizanje određenog nivoa nužno ne znači da će cela proizvodnja biti bazirana na tom nivou (Teletchea and Fontaine, 2013). Uzmimo za primer nivo 5, osim Atlantskog lososa (*Salmo salar*) kod koga vise od 95% gajenih jedinki širom sveta dolazi iz genetski unapređenih nasada, za druge vrste procenat je dosta niži, 22% kod kalifornijske pastrmke (*Oncorhynchus mykiss*) (Gjedrem and Baranski 2009; Gjedrem, 2010). Uprkos ovim ograničenjima, mi smo privremeno ocenili moguću povezanost između nivoa domestifikacije i proizvodnje, pod pretpostavkom da je sva proizvodnja zasnovana na nivou domestifikacije za svaku vrstu (Teletchea and Fontaine, 2013).

REZULTATI

Na prvi pogled se cinilo da postoji pozitivna veza izmenju nivoa domestifikacije i nivoa proizvodnje u 2009 (Slika 1). Ipak, kada je rađena dublja analiza varijabilnosti po nivou, pronađene su velike razlike, od minimalnih do maksimalnih [0, 6972] za nivo 1, [0, 237084] za nivo 2, [0, 329972] za nivo 3, [0, 2 418821] za nivo 4 i [0, 4 159919] za nivo 5. Na primer, uprkos tome sto su klasifikovane kao nivo 2, 6 vrsta (8% vrste na ovom nivou) proizvelo je vise od 150000 tona 2009., među kojima su i vrste *Seriola*

quinqueradiata i *Misgurnus anguillicaudatus.* Nasuprot tome, sedam vrsta (23%) klasifikovanih na najvisem nivou, proizvelo je manje od 1000 tona, među kojima je bilo 4 vrste jestera (*Acipenser* spp).



Slika 1. Poređenje nivoa proizvodnje (FAO baza podataka, vrednosti iz 2009. godine) po nivou domestifikacije (Teletchea and Fontaine, 2013) za 250 vrsta riba koje se nalaze na FAO-voj listi. Da pojasnimo, naznačene su samo pozitivne standardne devijacije. Broj iznad svakog histograma pokazuje broj vrsta po nivou.

DISKUSIJA

Ako uzmemo u obzir prirodu podataka u FAO-voj bazi podataka (Klinger et al., 2013), danas je nemoguće sigurno zaključiti da li su nivoi domestifikacije i proizvodnje pozitivno povezani, kao sto je predloženo na Slici 1. Ipak, čini se da je ceo životni ciklus u zatočeništvu pozitivno povezan sa značajnom proizvodnjom za nekoliko vrsta (15 najviše proizvođenih vrsta u 2009. su dostigle nivo 4 i 5), iako to nije uvek slučaj, najverovatnije zato što su postojale jedinke iz divljine koje su korišćene za dobijanje gameta (Ottolenghi et al., 2004; Welcomme et al., 2010). Pored same domestifikacije, razni faktori, među kojima kapital, tehnologija, regulatorna ograničenja, marketing, pozitivan ili negativan uticaj na životnu sredinu, i dostupnost odgovarajućeg prostora u vodenim i kopnenim sredinama, su takođe razlog što određene vrste mogu ili ne mogu da dostignu visoke nivoe proizvodnje (Le François et al., 2010; Suquet 2010; Klinger et al., 2013).

Analiza je ukazala na to da iako su brojne vrste daleko od procesa domestifikacije (Balon, 2004; Bilio, 2008; Teletchea and Fontaine, 2013), samo je oko 7% globalne proizvodnje riba (33 miliona tona u 2009. godini) zahtevalo unos riba iz divljine (kombinovana proizvodnja vrsta nivoa 1, 2 i 3). Ipak, ovaj procentualni iznos je verovatno dosta viši obzirom da je delić (nepoznat) proizvodnje vrsta klasifikovanih nivoima 4 i 5 takođe zahtevao unos riba iz divljine (Bartley et al., 2009; Gjedrem and Baranski, 2009). Potrebno je bolje poznavanje procenata globalne proizvodnje u akvakulturi koja je zasnovana na unosu iz divljine da bi se bolje razumeo spektar trenutne proizvodnje ribe (Klinger et al., 2013), I da bi se ocenila održivost različitih načina gajenja riba (Ottolenghi et al., 2004; Bilio, 2008).

Sve u svemu, ovi rezulati ukazuju da je u prošlih deset godina akvakultura prošla kroz sve stupnjeve kao i poljoprivreda sa jako velikom proizvodnjom u 2009. godini – tada je gajenje bilo zasnovano na nekoliko domestifikovanih vrsta. U budućnosti, industrija može da nastavi da se fokusira na nekoliko domestifikovanih ribljih vrsta, koje se uvoze u mnogim zemljama širom sveta. Industrija takođe može da se okrene diverzifikaciji među različitim vrstama primarno se fokusirajući na domestifikaciju domaćih vrsta. Prednosti i mane ova dva glavna scenarija su posebno razmatrane u radovima De Silva et al. (2009), Diana (2009), and Teletchea and Fontaine (2013).

INTRODUCTION

The agricultural world today is dominated by a few mammal species that were domesticated over the past 12 000 years (Diamond, 2002). In particular, the five major species (cattle, pig, sheep, goat and horse) represent nearly 94% of mammalian livestock today. As a result, a clear dichotomy now exists between the numerous wild (from hunting) and the few domesticated mammals (produced in farms) used for human consumption. Similar to agriculture, aquaculture is often viewed as the only solution that can provide more seafood given that harvesting wild marine stocks are either stabilizing or more probably declining since the late 1980s (Watson and Pauly, 2001; FAO, 2012). Indeed, it is unlikely that fisheries will be able to supply more aquatic food products than today, *ca.* 90 million tones per year, including both marine and inland captures (FAO, 2012). Yet, compared to agriculture, aquaculture is a considerably younger sector that relies strongly on natural sources to farm numerous species with various production levels (Bostock et al., 2010; Jobling, 2010).Among the 313 species or group of species recorded in the United Nation's Food and Agriculture Organization (FAO) database in 2009, which have been farmed at one time since 1950, 28.4% were no longer being produced in 2009 and 17.9% produced less than 100 t. Only 12.1% produced more than 100 000 t (Teletchea and Fontaine, 2013). In addition, and more importantly, the duration of consecutive production recorded in the FAO database was very short for most species or groups of species, only one year for 10.2% and from two to five years for 15.3%; only 18.8% have been farmed for more than 40 years (Teletchea and Fontaine, 2013).

To better describe the various strategies for fish production (Ottolenghi et al., 2004; Welcomme et al., 2010; Klinger et al., 2013), a new classification comprising five levels of "domestication" with 1 being the least to 5 being the most domesticated was recently proposed (Teletchea and Fontaine, 2013). Among the 250 species recorded in the FAO database in 2009 (*i.e.*, excluding group of species), 39 belong to the level 1 (first trials of acclimatization to the culture environment, *e.g., Anguilla rostrata, Scardinius erythrophthalmus*, 75 to the level 2 (also known as capture-based aquaculture, *e.g., Thunnus thynnus, Aspius aspius*), 61 to the level 3 (entire life cycle closed in captivity with wild inputs, *e.g., Solea senegalensis, Rutilus rutilus*), 45 to the level 4 (entire life cycle closed in captivity without wild inputs, *e.g., Pagrus pagrus, Sander lucioperca*), and 30 to the level 5 (selective breeding programme is used focusing on specific goal, *e.g., Salmo salar, Cyprinus carpio*). As of now, 70% of the 250 species listed in the FAO belong to the first three levels of domestication thatdepend on the availability of wild resource (Ottolenghi et al., 2004). In contrast, only a few species, or more accurately populations, can be considered truly domesticated (Balon, 2004;Bilio, 2008), *i.e.*, an animal selectively bred in captivity and modified from its wild ancestors making it more useful

to humans who control the animal's breeding and food supply (Clutton-Brock, 1999), similar to cattle or sheep.

Based on this new classification, one may ask if farmed species must be domesticated to reach a significant production, or in other terms, whether the levels of production and domestication are positively correlated.

MATERIALS AND METHODS

Such analyses require having accurate data on: (i) the level of domestication for each species, (ii) the global production per species, and (iii) the percentage of the production per domestication level for each species. Based on the databases of Teletchea and Fontaine (2013) and FAO (http://www.fao.org/fishery/en) respectively, the first two kinds of data are available. Yet, given the actual nature of data provided to the FAO by its members and associated nations Klinger et al., 2013), it is currently impossible to know how much of the production of a species is based on each domestication level. Indeed, as already noticed, reaching a particular level does not necessary imply that the entire production is based on this level (Teletchea and Fontaine, 2013). For instance for the level 5, except for the Atlantic salmon (*Salmo salar*) for which more than 95% of farmed individuals worldwide is coming from genetically improved stocks, for other species the percentage is generally much lower, such as 22% in rainbow trout (*Oncorhynchus mykiss*) (Gjedrem and Baranski 2009; Gjedrem, 2010). Despite these limits, we tentatively estimated the possible relation between the levels of domestication and production, assuming that all production is based on the level of domestication for each species (Teletchea and Fontaine, 2013).

RESULTS

At first sight, it seemed that there was a positive link between the levels of domestication and the levels of production in 2009 (Figure 1). Yet, when analyzing more deeply the variability per level, large differences were found, ranging from a min and a max of [0, 6972] for the level 1, [0, 237084] for the level 2, [0, 329972] for the level 3, [0, 2 418821] for the level 4 and [0, 4 159919] for the level 5. For instance, despite being classified at the level 2, six species (8% of the species at this level) produced more than 150000 tonnes in 2009, among which Japanese amberjack (*Seriola quinqueradiata*) and pond loach (*Misgurnus anguillicaudatus*). Conversely, seven species (23%) classified at the highest level produced less than 1000 tonnes, among which four species of sturgeons (*Acipenser* spp).

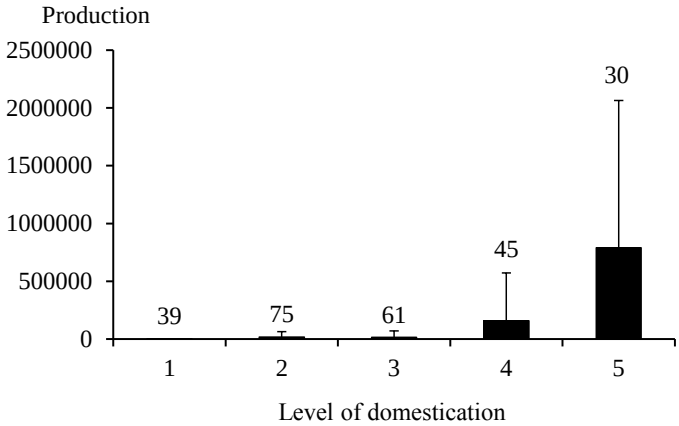


Figure 1. Comparison of the level of production (FAO database, 2009 values) per level of domestication (Teletchea and Fontaine, 2013) for the 250 finfish species listed in the FAO. For clarity, only positive standard deviations are indicated. The number over each histogram indicates the number of species per level.

DISCUSSION

Given the actual nature of the data in the FAO database (Klinger et al., 2013), it is today impossible to definitely conclude whether the levels of domestication and production are positively linked, as suggested in the Figure 1. Nevertheless, it seems that fully closing the life cycle in captivity was positively related with a significant production forseveral species (the top 15 most produced species in 2009 all have reached levels 4 or 5), albeitit was not always the case, more probably because wild resource was available for seeding (Ottolenghi et al., 2004; Welcomme et al., 2010). Besides domestication *per se*, various factors, among which capital, technology, regulatory constraints, marketing, environmental externalities, and the availability of suitable space in aquatic and terrestrial environments, also explain why a given species may or may not reach a significant production (Le François et al., 2010; Suquet 2010; Klinger et al., 2013).

The present analysis also allowed highlighting that even though numerous species are far from being domesticated (Balon, 2004; Bilio, 2008; Teletchea and Fontaine, 2013), only about 7% of the global finfish production (33 million tons in 2009) seemed to require wild inputs (production of levels 1, 2 and 3 combined). Yet, this percentage is most likely much higher given that a fraction (unknown) of the production of the species classified at levels 4 and 5 also relied on wild inputs (Bartley et al., 2009; Gjedrem and Baranski, 2009). A better understanding of the percentage of the global aquaculture production that is based on wild inputs is much needed in order to better traduce the current spectrum of finfish production (Klinger et al., 2013), and evaluate the sustainability of different farming practices (Ottolenghi et al., 2004; Bilio, 2008).

Altogether, these results imply that aquaculture has followed nearly the same path as agriculture in the past decades with the bulk of the production in 2009based on the farming of a few domesticated finfish species. In the future, the industry might continue to focus on few truly domesticated species, which have generally been imported in numerous countries worldwide, or really proceeds with inter-specific diversification by focu-

sing primarily on the domestication of native species. The advantages and drawbacks of these two main scenarios are discussed notably in De Silva et al. (2009), Diana (2009), and Teletchea and Fontaine (2013).

REFERENCES

Balon EK (2004): About the oldest domesticates among the fishes. Journal of Fish Biology 65: 1-7.

Bartley DM, Nguyen TTT, Halwart M, De Silva SS (2009) Use and exchange of aquatic resources in aquaculture: information relevant to access and benefit sharing. Reviews in Aquaculture 1, 157–162.

Bilio M (2008): Controlled reproduction and domestication in aquaculture. European Aquaculture Society, Oostende.

Bostock J, McAndrew B, Richards R, Jauncey K, Telfer T, Lorenzen K, Little D, Ross L, Handisyde N, Gatward I, Corner R (2010): Aquaculture: global status and trends. Philosophical Transactions of the Royal Society: B-Biological Sciences 365: 2897–2912.

Clutton-Brock J (1999): A Natural History of Domesticated Mammals. Cambridge: Cambridge University Press.

De Silva SS, Nguyen TTT, Turchini GM, AmarasingheUS, Abery NW (2009): Alien species inaquaculture and biodiversity: a paradox in food production.Ambio 38: 24–28.

Diamond J (2002) Evolution, consequences and future of plant and animal domestication. Nature 418: 700–707.

Diana JS (2009): Aquaculture production and biodiversity conservation.BioScience 59: 27-38.

FAO (2012) : The state of the world fisheries and aquaculture. Rome: Food and Agriculture Organization of the United Nations.

Gjedrem, T (2010): The first family-based breeding program in aquaculture. Reviews in Aquaculture 2, 2–15.

Gjedrem T, Baranski M (2009): Selective breeding in aquaculture: An introduction. Springer, London.221 p.

Jobling M (2010): Chapter 4.Farmed fish and their characteristics. In: Finfish aquaculture diversification (eds Le François N, Jobling M, Carter C, and Blier P), CABI, Oxfordshire, pp. 88-99.

Klinger DH, Turnipseed M, Anderson JL, Asche F, Crowder LB, Guttormsen AG, Halpern BS, O'Connor MI, Sagarin R, Selkoe KA, Shester GG, Smith MD, Tyedmers P (2013): Moving beyond the fished and farmed dichotomy. Marine Policy 38: 369-374.

Le François NR, Otton D, Werstink G (2010): Chapter 5. Considerations for the selection and commercialization of new or alternate species. In: Finfish aquaculture diversification (edsLe François N, Jobling M, Carter C, Blier P). CABI, Oxfordshire, pp. 100–114.

Ottolenghi F, Silvestri C, Giodano P, Lovatelli A, New MB (2004): Capture-based Aquaculture, The Fattening of Eels, Groupers, Tuna and Yellowtails. FAO, Rome: i-xxiv + 1-308.

Suquet M (2010): Chapter 6. A systematic market approach to species diversification: a French case study. In: Finfish Aquaculture Diversification (edsLe François N, Jobling M, Carter C, Blier P). CABI, Oxfordshire, pp. 115–131.

Teletchea F, Fontaine P (2013): Levels of domestication in fish: implications for the sustainable future of aquaculture. Fish and Fisheries DOI: 10.1111/faf.12006 (*in press*)

Welcomme RL, Cowx IG, Coates D, Béné C, Funge-Smith S, Halls A, Lorenzen K (2010): Inland capture fisheries. Philosophical Transactions of the Royal Society: B-Biological Sciences 365, 2881–2896.

Watson R, Pauly D (2001): Systematic distortions in world fisheries catch trends. Nature 414: 534–536.